The Scientific Context for Exploration of the Moon

NRC Report

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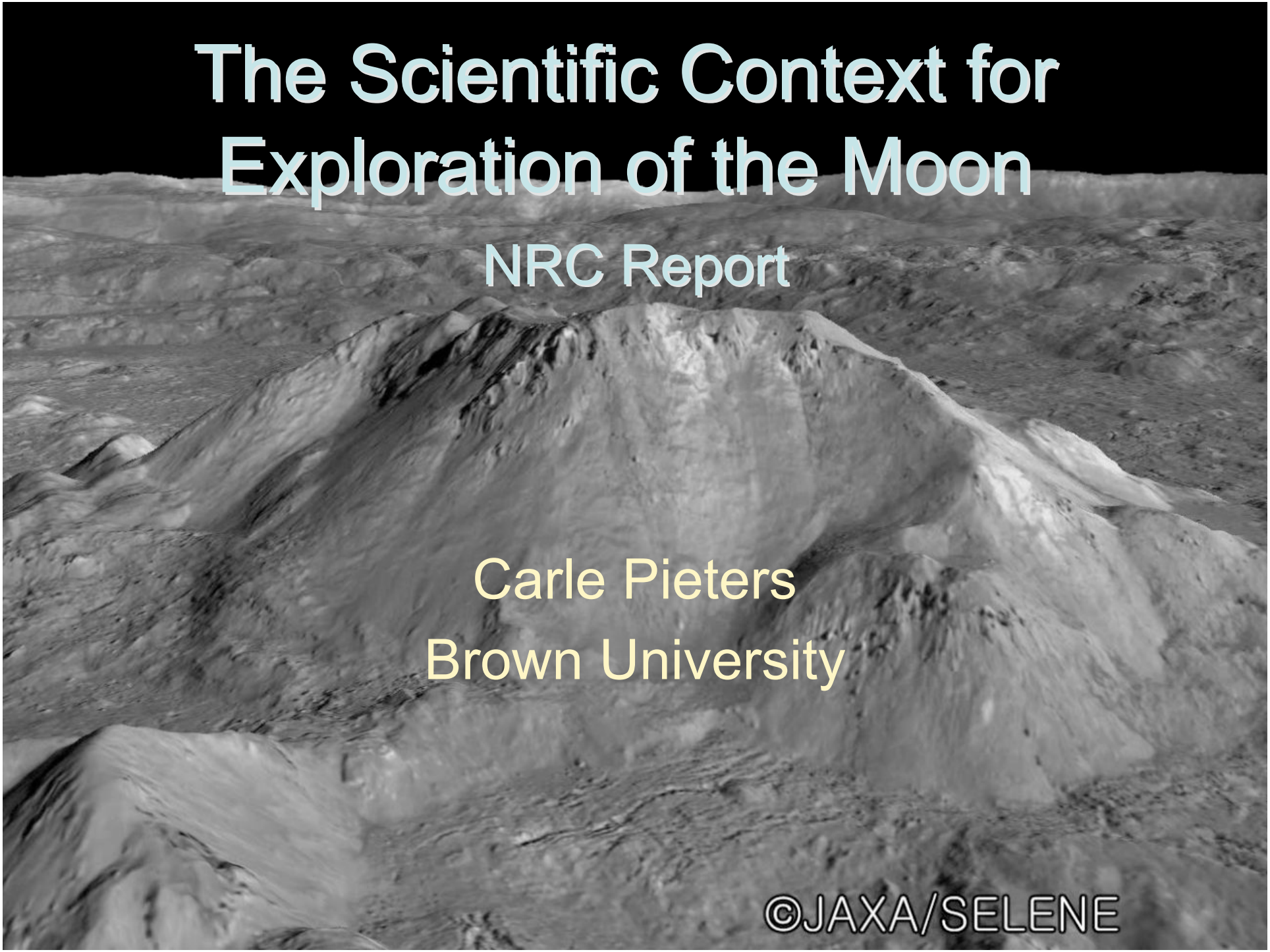


Why the Moon?

- Apollo was exciting

  …… but been there, done that.
- We have enough problems on Earth to solve: Climate change, hunger, war….

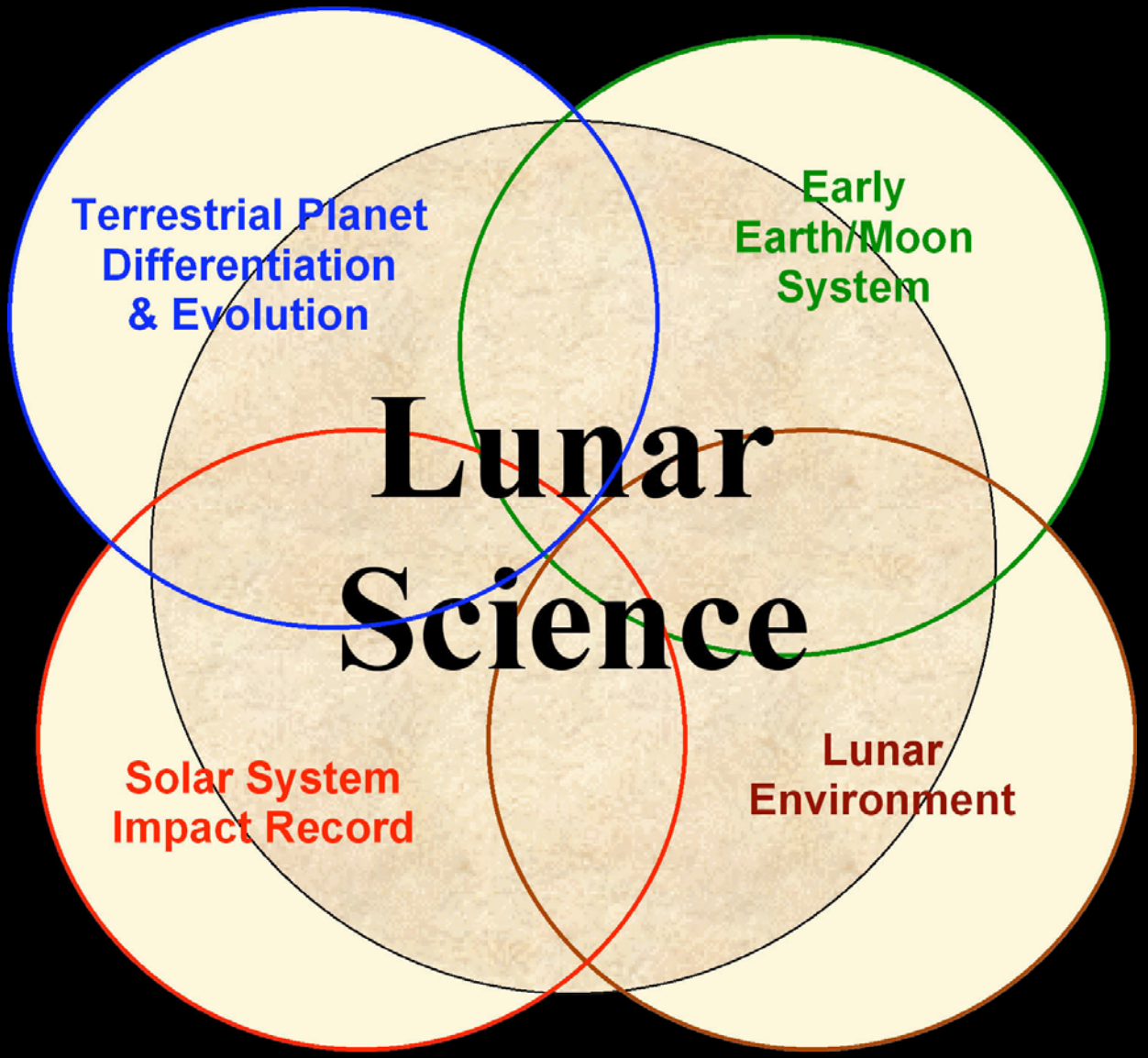
Furthermore,

- Mars and the search for life are compelling…
- Titan and Europa are exotic challenges….
- The Big Bang, strings, dark matter are fundamental….

Because…..

- The early history of the Earth-Moon system is uniquely documented and accessible on the Moon.
- The Moon is the cornerstone to understanding the terrestrial planets (our home).
- The Moon provides a variety of near-by extra-terrestrial environments for science and exploration activities.
- Exploration of the Moon is an international activity.

Overarching Themes of Solar System Exploration



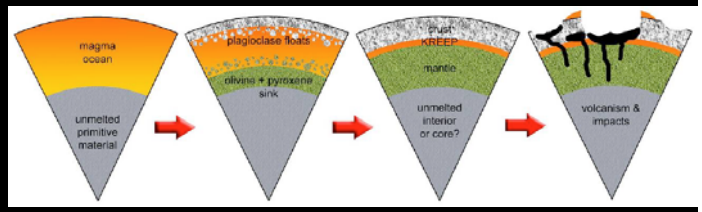
NRC 2007 Report: http://books.nap.edu/catalog.php?record_id=11954

Post-Apollo Scientific Hypotheses

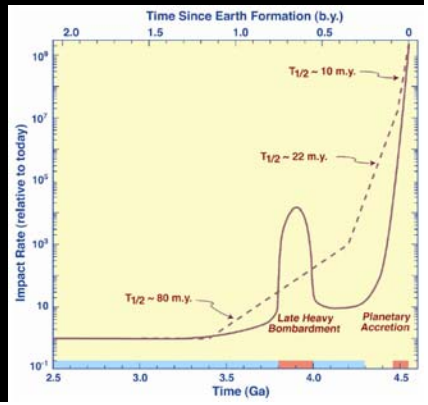
The context for understanding the origin and evolution of the Moon

- **The giant impact hypothesis & the Earth-Moon system**
  Explains the origin of the Moon as being assembled from debris after the impact of a Mars-sized object with the early Earth.

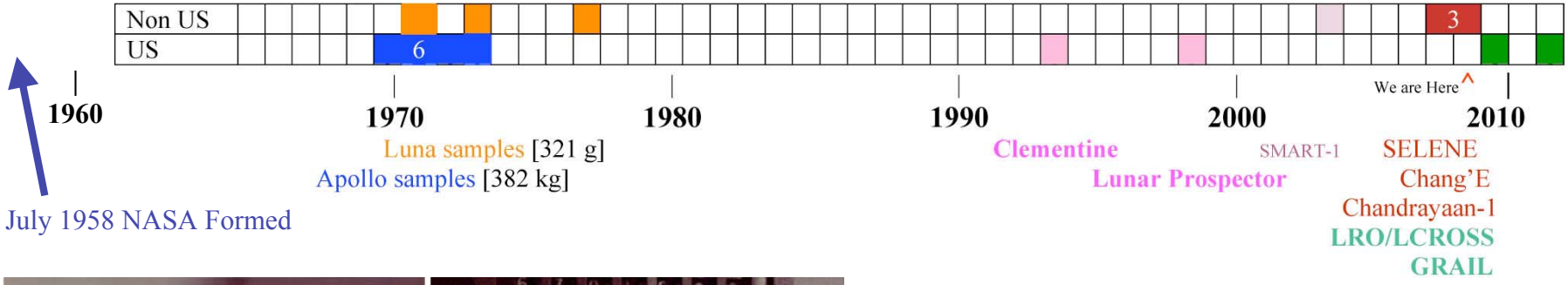
- **The lunar magma ocean hypothesis**
  Governs understanding of the formation of lunar rocks, and suggests that the outer portions of the Moon were entirely molten. Differentiation of the vast magma body resulted in the formation of the earliest crust and mantle.



- **The terminal cataclysm (Late Heavy Bombardment) hypothesis**
  Concerns the character of the impact flux in the first 600 Ma. It proposes that the large multi-ringed impact basins observed on the Moon were formed in a brief pulse near 4 Ga ago, well after debris left over from solar system formation had died away. [An alternate hypothesis is that the rate of impacts declined smoothly with time and no cataclysm occurred.]



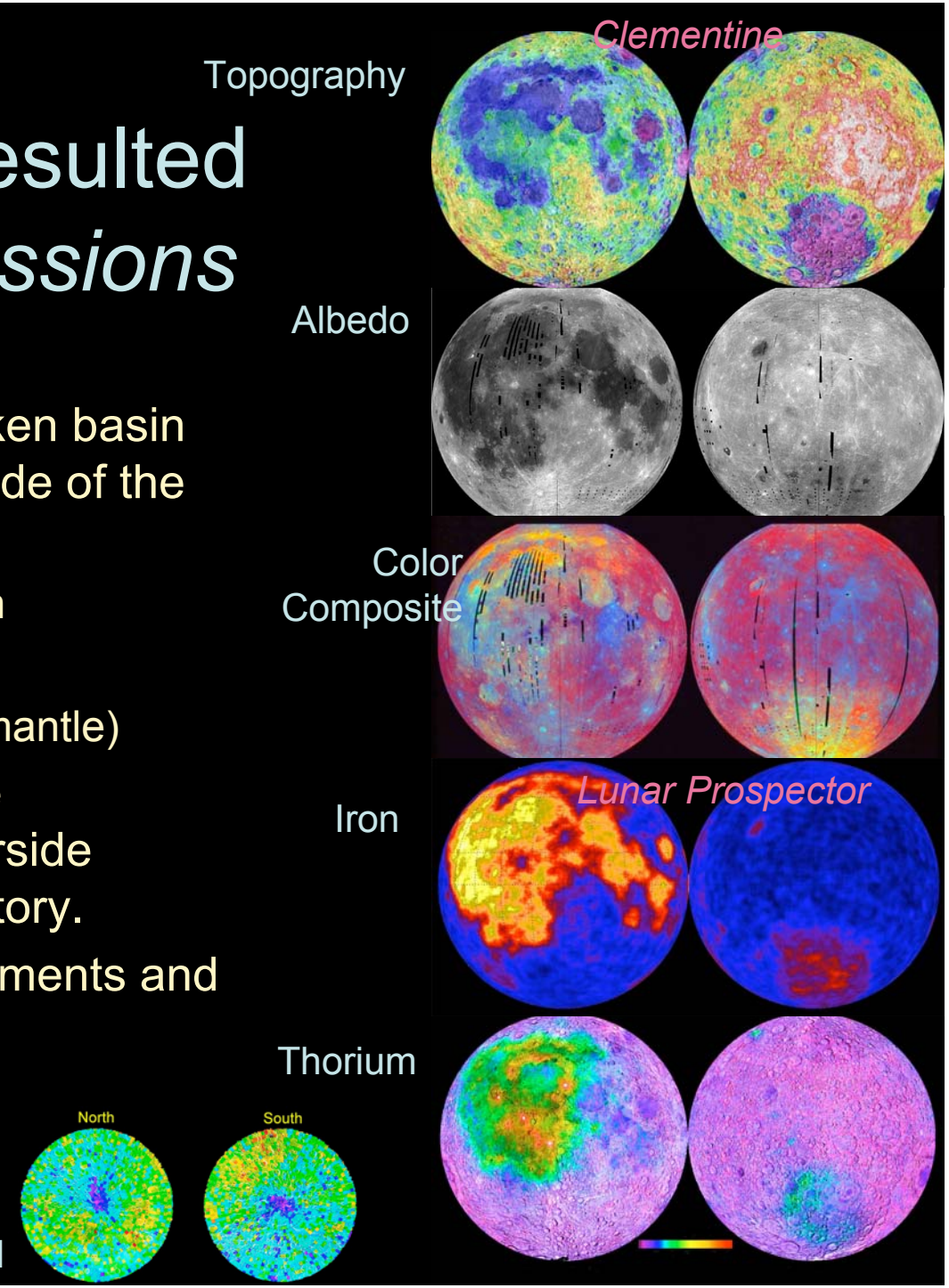
Lunar Exploration Timeline: Return after a Long Drought



- The Apollo/Luna samples brought new and fundamental understanding of planetary evolution (and the Earth-Moon system).
- After decades of neglect, two very small missions were sent to the Moon. The small pulse of new data sparked several paradigm shifts.
- A fleet of sophisticated modern sensors are now *at last* exploring the Moon.

Paradigm Shifts resulted from *two small missions*

- The enormous South-Pole Aitken basin dominates the feldspathic farside of the Moon.
  - Largest and oldest lunar basin
  - Minor basalt fill
  - Iron-rich interior (lower crust/mantle)
- Heat producing elements were concentrated on the lunar nearside (Apollo sites) early in lunar history.
- The poles are unusual environments and may accumulate volatiles.

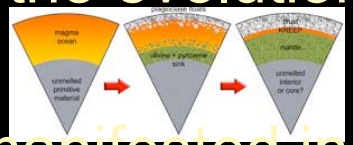


SCIENCE CONCEPTS (8)

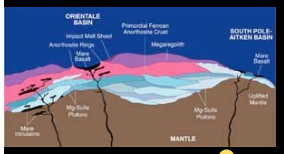
in order of Scientific Merit

Each includes several prioritized Science Goals (35).

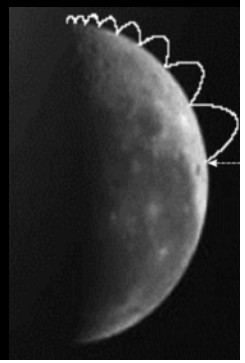
- **Concept 1:** The bombardment history of the inner solar system is uniquely revealed on the Moon
- **Concept 2:** The structure and composition of the lunar interior provide fundamental information on the evolution of a differentiated planet ★



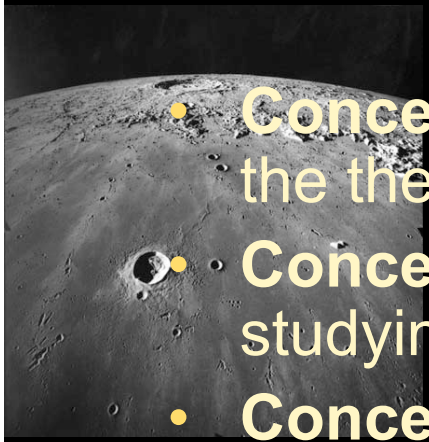
- **Concept 3:** Key planetary processes are manifested in the diversity of lunar crustal rocks



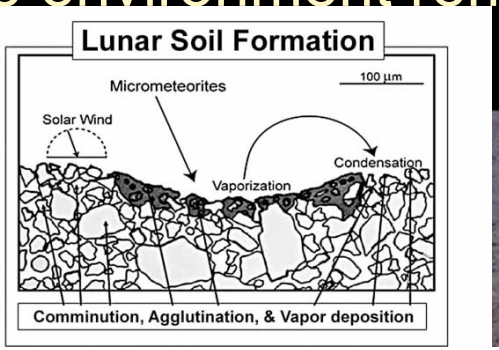
- **Concept 4:** The lunar poles are special environments that may bear witness to the volatile flux over the latter part of solar system history ★

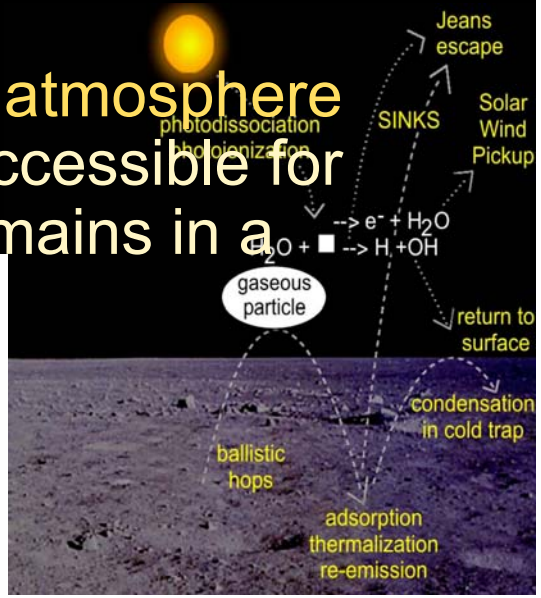


SCIENCE CONCEPTS (cont.)



- **Concept 5:** Lunar volcanism provides a window into the thermal and compositional evolution of the Moon
- **Concept 6:** The Moon is an accessible laboratory for studying the impact process on planetary scales
- **Concept 7:** The Moon is a natural laboratory for regolith processes and weathering on anhydrous airless bodies
- Concept 8: Processes involved with the atmosphere and dust environment of the Moon are accessible for scientific study while the environment remains in a pristine state ★





Consensus Statement

It is the unanimous consensus of the committee that the Moon offers profound scientific value. The infrastructure provided by sustained human presence can enable remarkable science opportunities if those opportunities are evaluated and designed into the effort from the outset. While the expense of human exploration can not likely be justified on the basis of science alone, the committee emphasizes that careful attention to science opportunity is very much in the interest of a stable and sustainable lunar program. A vigorous near term robotic exploration program providing global access is central to the next phase of scientific exploration of the Moon and is necessary both to prepare for the efficient utilization of human presence and to maintain scientific momentum as this major national program moves forward.

Findings…

Principal Finding: Lunar activities apply to broad scientific and exploration concerns.

Finding 1: Enabling activities (e.g., fundamental research program, data analysis program) are critical in the near term.

NASA should make a strategic commitment to stimulate lunar research and engage the broad scientific community by establishing two enabling programs, one for fundamental lunar research and one for lunar data analysis.

Finding 2: Strong ties with international programs are essential.

NASA should explicitly plan and carry out activities with the international community for scientific exploration of the Moon in a coordinated and cooperative manner.

Finding 3: Exploration of the South Pole -Aitken Basin remains a priority

NASA should develop plans and options to accomplish the scientific goals through single or multiple missions that increase understanding of the South Pole-Aitken Basin.

Finding 4: Diversity of lunar samples is required for major advances.

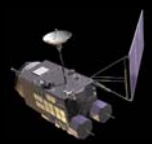
Landing sites should be selected that can fill in the gaps in diversity of lunar samples.

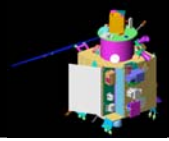
Finding 5: The Moon may provide a unique location for observation and study of Earth, near-Earth space, and the universe.

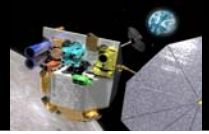
NASA should consult scientific experts to evaluate the suitability of the Moon as an observational site.

International Lunar Exploration

	KAGUYA [JAXA]	Chang'E [CNSA]	Chandrayaan 1 [ISRO]	LRO [NASA]	GRAIL [NASA]
Launch	2007	2007	2008	2009	2011
Orbit	100 km polar circular	200 km polar circular	100 km polar circular	50 km polar circular	~ 50 km polar circular
Objectives	Study lunar origin and evolution; develop technology for future lunar exploratio n	Surface structure, topography, composition; particle environment	Simultaneous composition and terrain mapping; demonstrate impact probe	Improve geodetic net; evaluate polar areas; study radiation environment	Determine interior structure; thermal evolution; model terrestrial planets
Payload	relay satellites, multispec imager, spec profile, stereo, X-ray spec, g-ray spec; laser altimeter; radar sounder, magnetometer, plasma imager	4-band micro-wave, X-ray, g-ray, stereo, interferometer, laser altimeter, energetic ion s	hires stereo, wedge imager, laser altimeter, HE x-ray, impact probe+ X-ray spec, ions, radiation, spec profile, miniSAR, NIR image spec	hires camera, laser altimeter, UV, radiation, radiometer, neutron spec, miniRF; LCROSS-impact	2 spacecraft with ~200km separation and Ka-band ranging system; [90-day science phase]



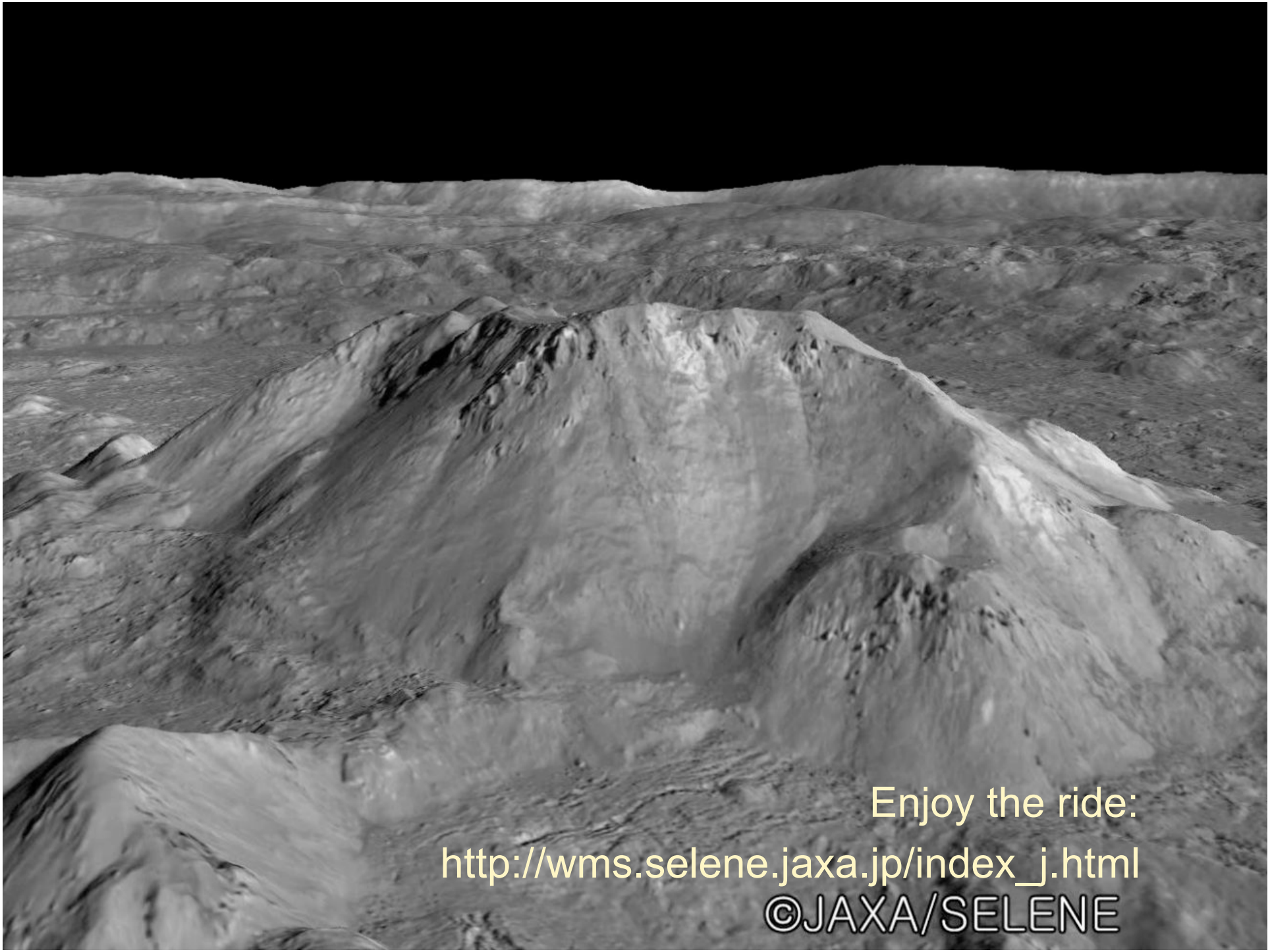




Still Much Undone….

In the wings (Phase A and pre-Phase A…..

- LADEE orbiter (NASA-SMD)
- Lunar Explorations Orbiter (DLR- Germany)
- MoonLITE penetrators (United Kingdom)
- Chandrayaan-2 lander/rover (India & Russia)
- Lunar lander (China)
- SELENE II lander (Japan)
- Telecom orbiter (NASA-SOMD)
- Mini-lander network nodes (2) (NASA-SMD)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